

Channel Capacity Simulation of Peer-to-Peer Spread Spectrum Satellite Transponders

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Spread Spectrum Wideband Transponder (SSWBT) Goals

High data rate SS communications

- Provide 10 kbps for [mobile] digital voice
- 100's of kbps for fixed systems with directional transmit antennas
- All users can receive higher data rates

Low cost, simple hardware

- <1 Watt for digital voice
- Small patch antennas (No pointing)

Experimental Testbed

- Experimentation with many modulation and coding systems
- Basis for future network of amateur LEOs

The EXPRESS Pallet

Modular experimental platform on the International Space Station designed for quick deployment

Pro

- No need to develop our own launch vehicle or power system
- "Free Ride" with JPL optical communications experiment
- Satellite provides line of sight coverage over 1000+ mile distances

Con

- ISS is several years behind schedule
- Funding status of JPL experiment is unknown
- Short passes, ~15 minutes 3-4x per day

System Design

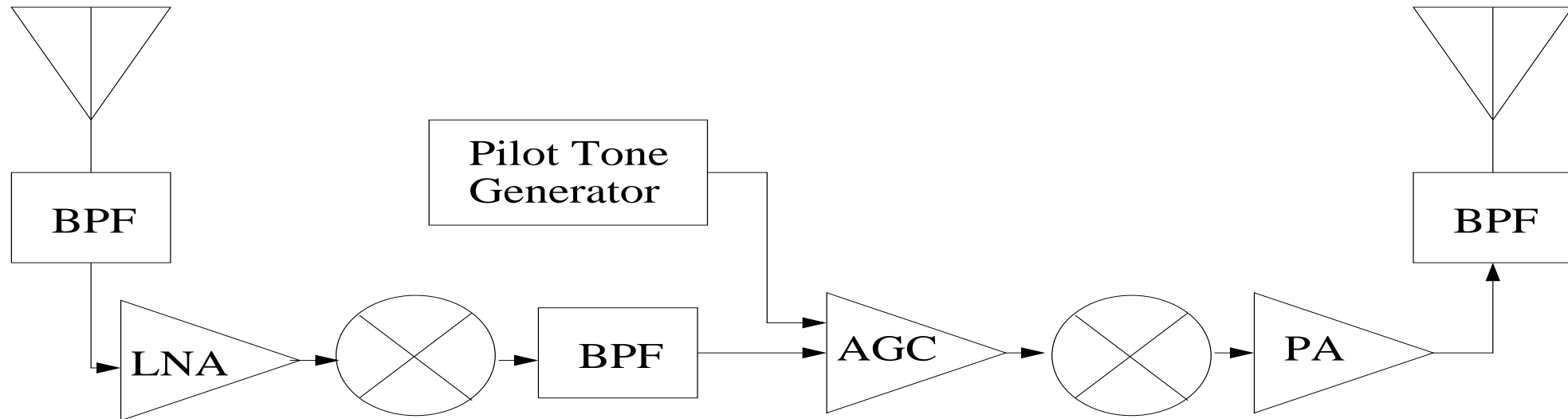
Simple Space Segment

- "Bent Pipe" linear transponder
- 25 Watts output
- Unmodulated PN Sync sequence for rapid acquisition and automatic power control of ground stations
- Dual Nadir-pointing patch antennas

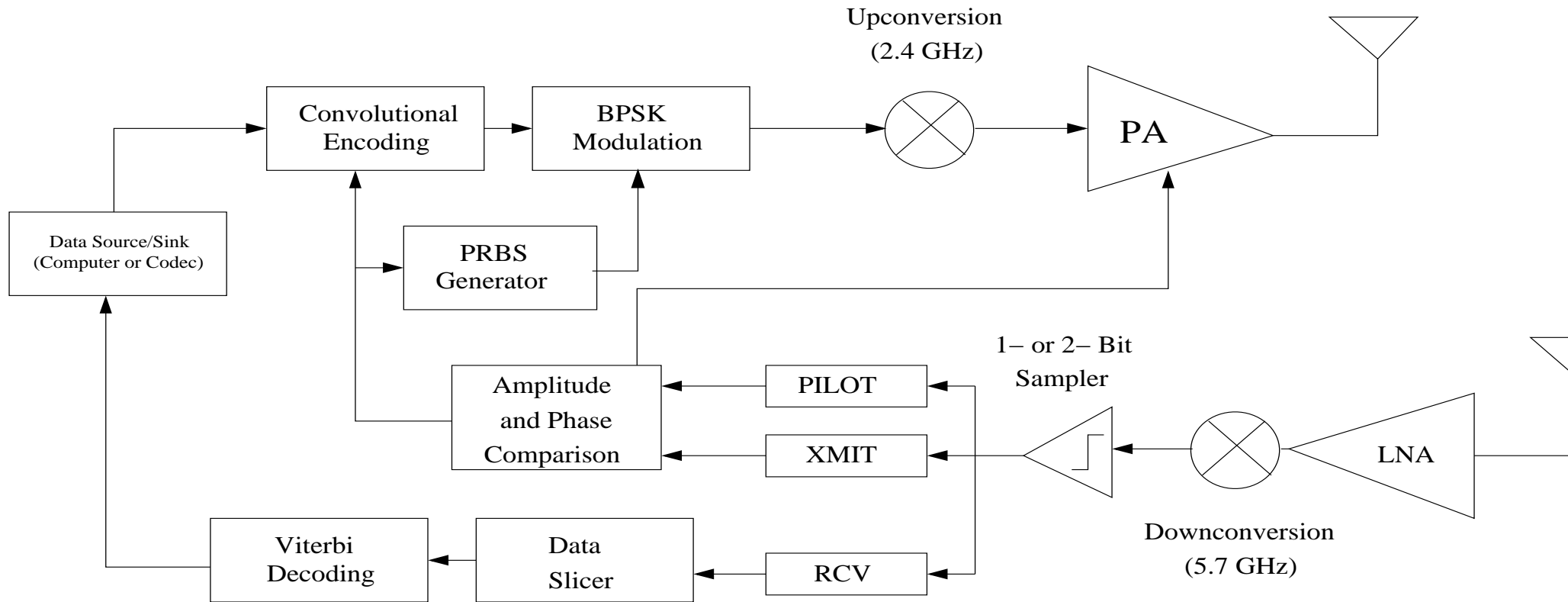
Ground Station

- BPSK Direct Sequence Spread Spectrum
- Forward Error Correction (FEC)
- Automatic Power Control with up to 1 Watt out
- Dual Zenith-pointing patch antennas

Space Segment Architecture



Ground Station Architecture



Simulation

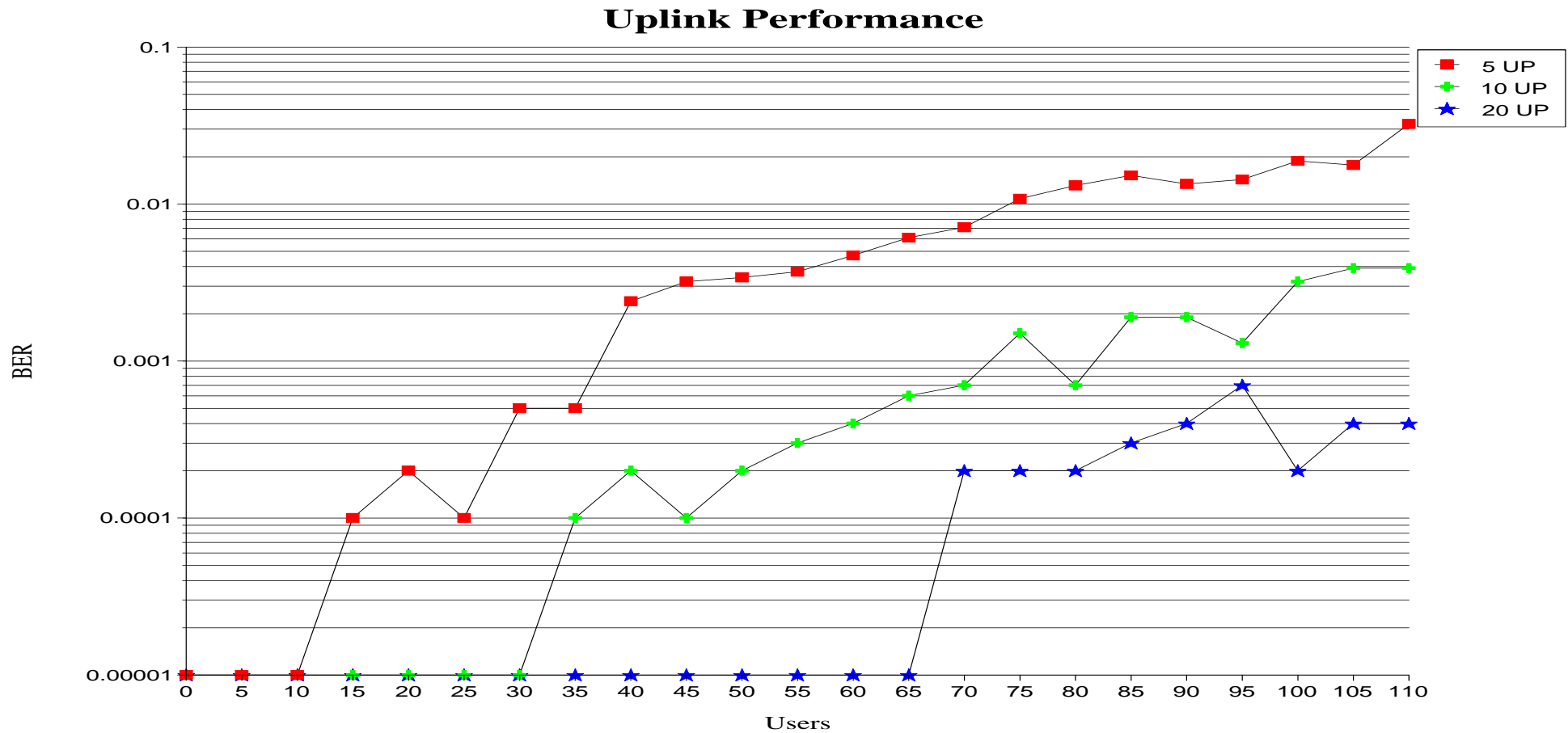
Chip-accurate Performance Simulation

- AWGN Channel simulator
- Linear and non-linear transponders
- 10K Bits simulated for each performance point (1 second of data)
- Did not simulate FEC

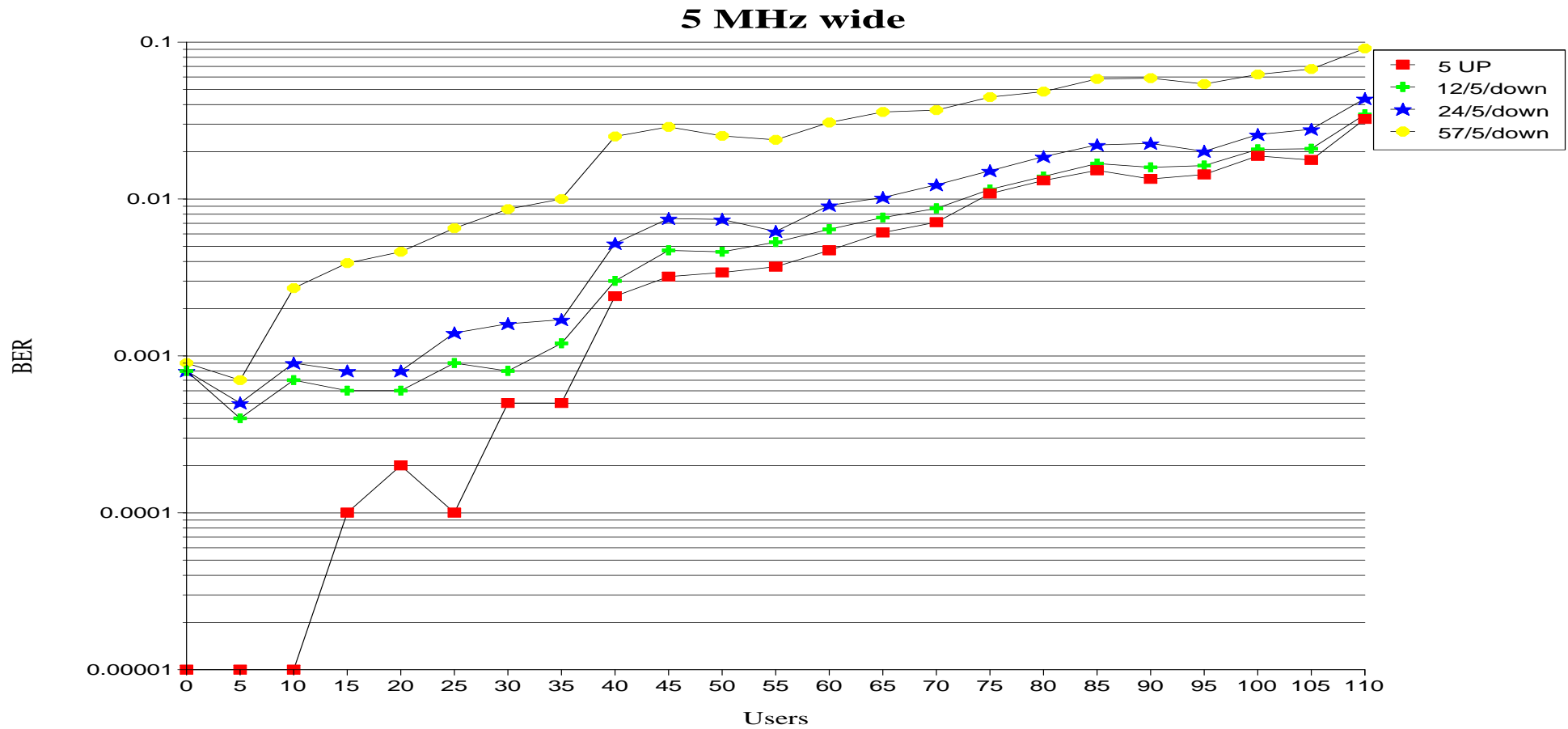
Used GOSSIP simulation environment

- System and network simulation environment
- Basic computational elements written in C++
- Connectivity and simulation control expressed in GUILE (Scheme/LISP)
- 10K Bits, 20Mchips, 110 interferers (worst case) simulated in 50 minutes on an Athlon 800
- Free Software (GPL License)
- See <http://gossip.sourceforge.net> for more info

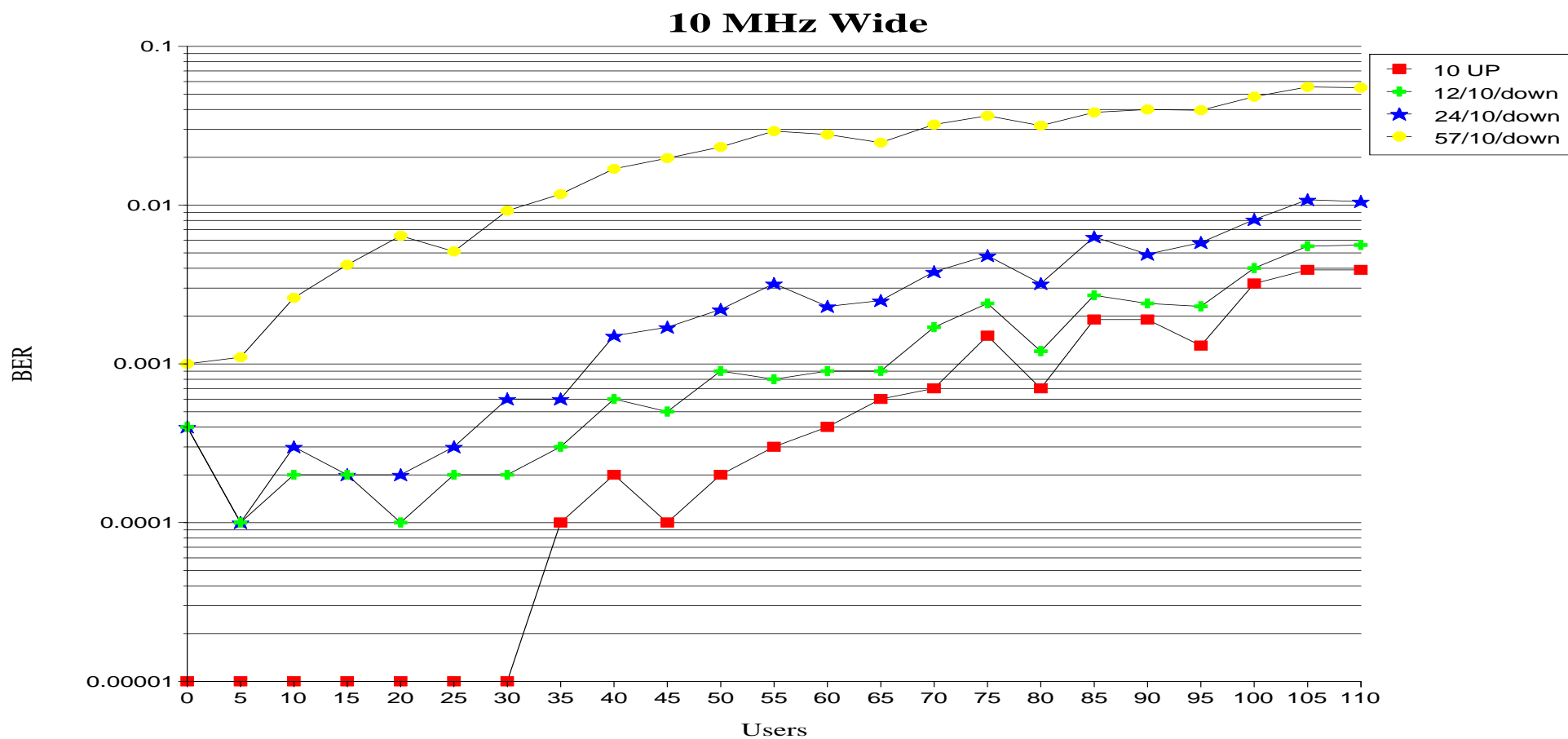
Uplink BER (at satellite)



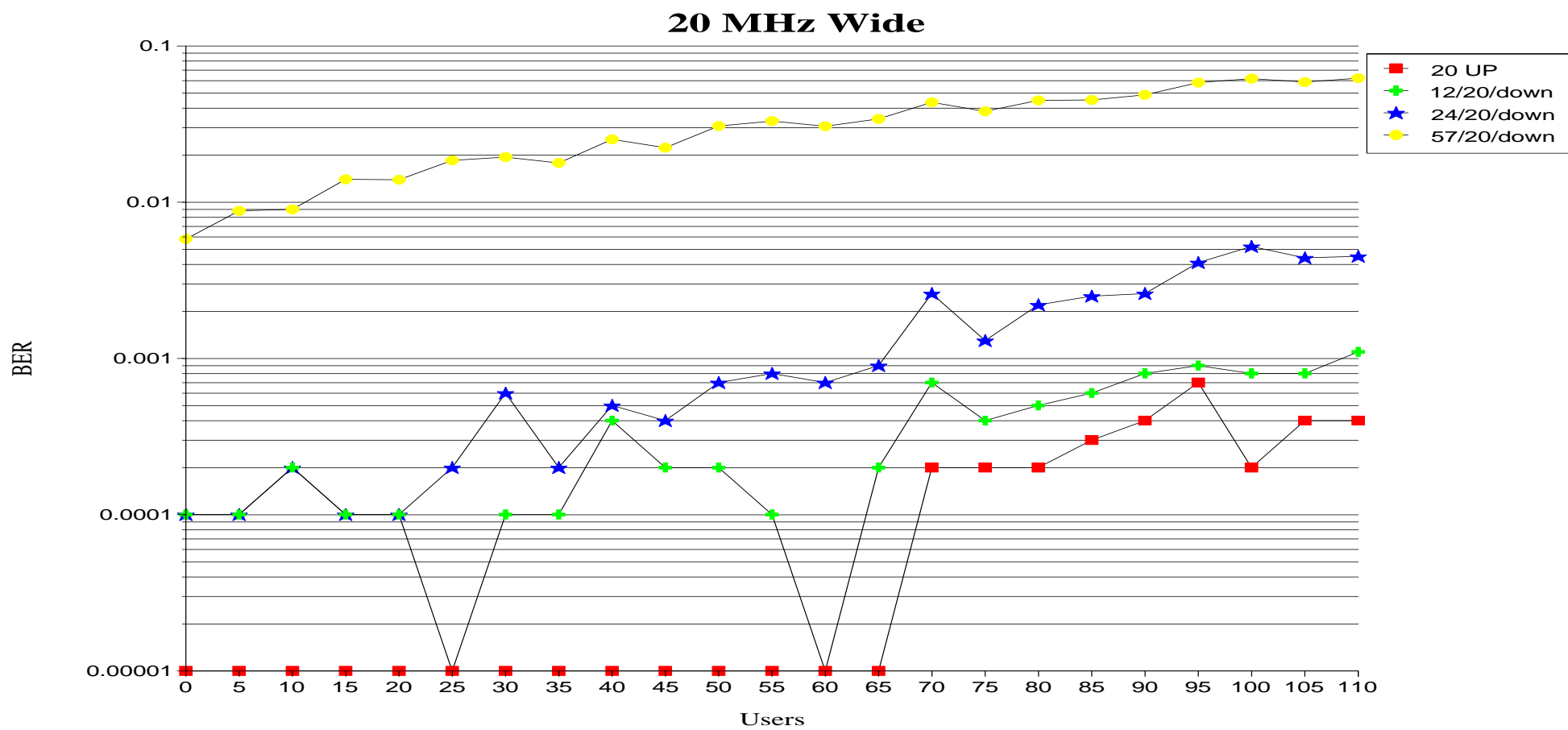
5 MHz Wide (2.5 Mchips/sec)



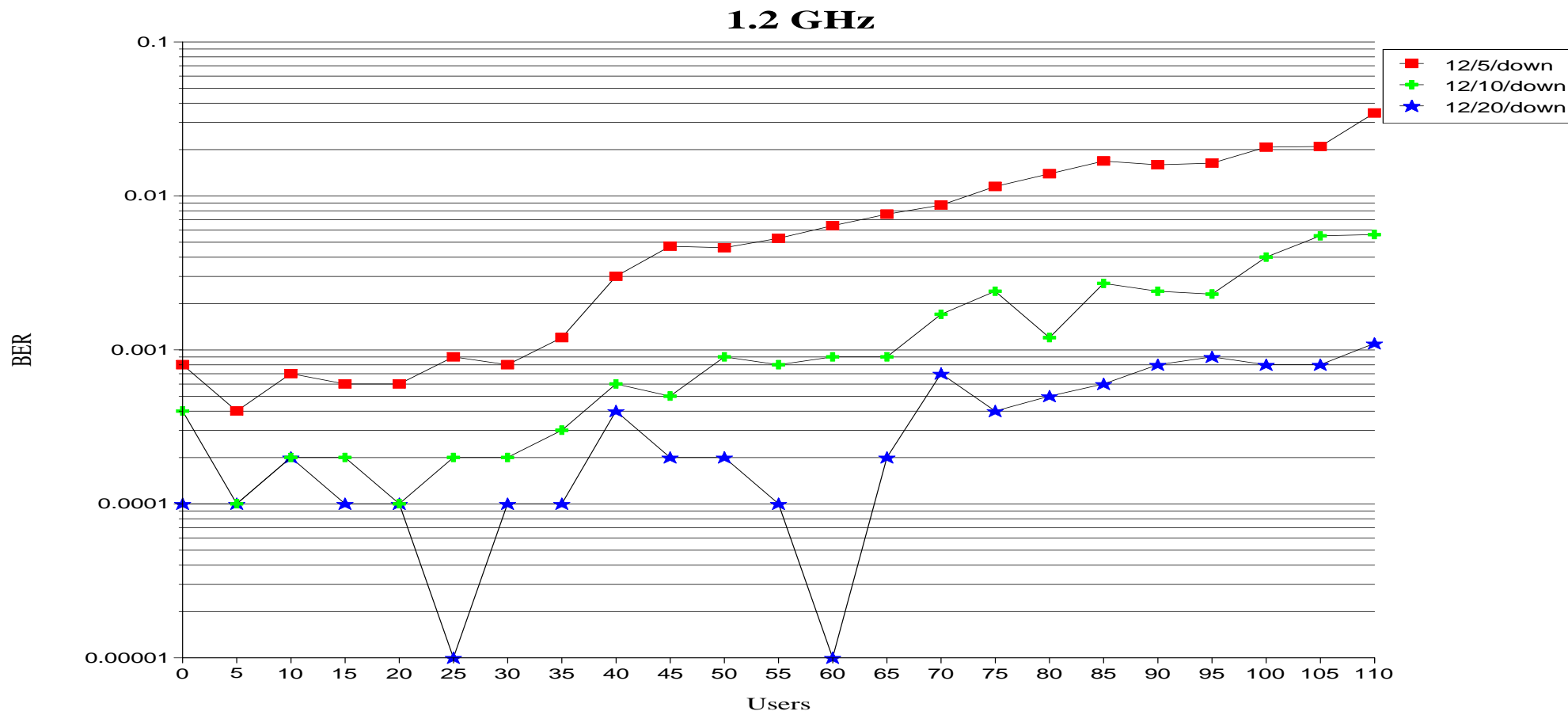
10 MHz Wide



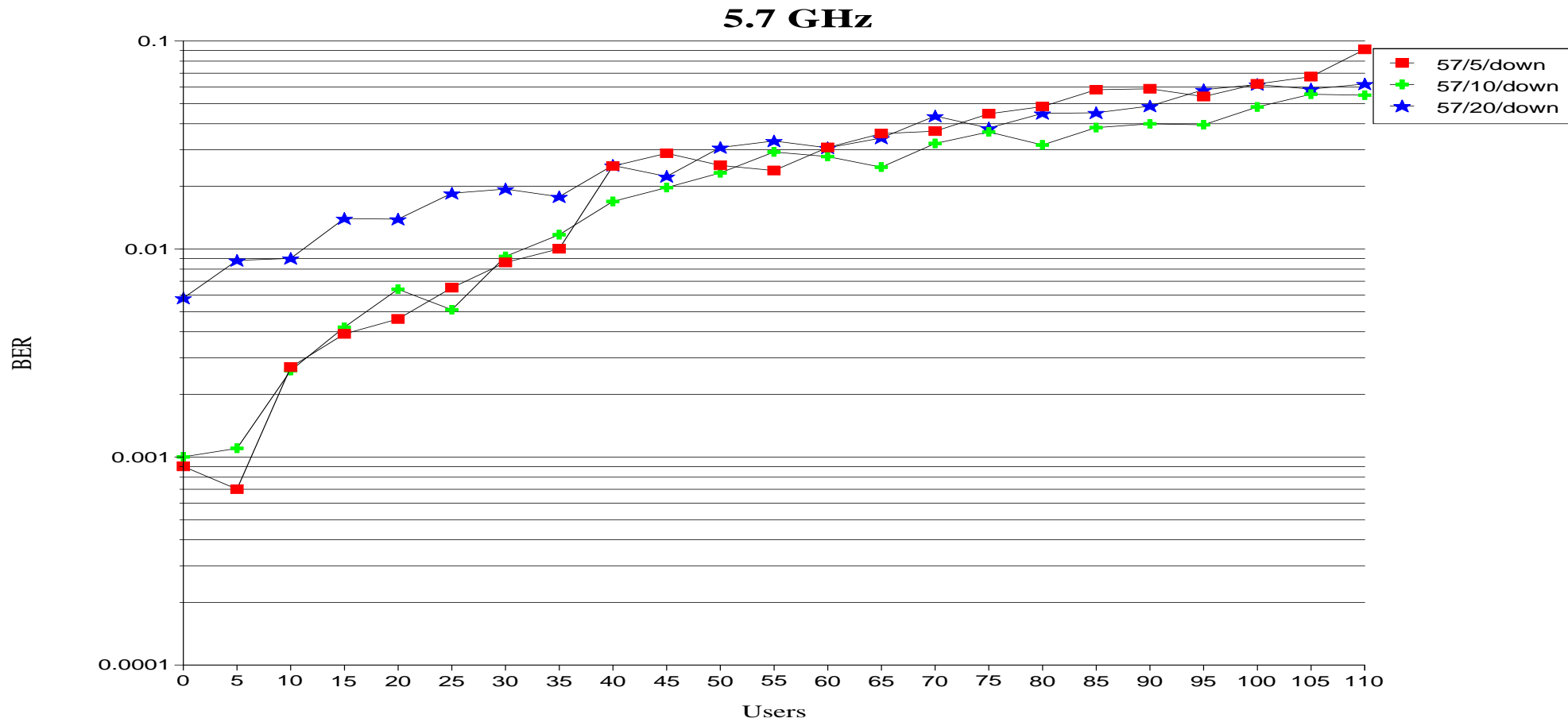
20 MHz Wide



Results for 1.2 GHz Downlink



Results for 5.7 GHz Downlink



Channel Characteristics

Uplink is interference limited

- Uplink power per signal constant
- Downlink power per signal shrinks with more signals present

Downlink is power limited

- Power is divided among all users, and retransmission of noise
- Automatic power control is critical to proper sharing of channel

Error rate is determined by

- Congestion in the uplink (mutual interference)
- Path Loss in downlink
- Downlink power sharing in transponder

Performance Tradeoffs

Signal Bandwidth

- Wider accommodates more users (higher spreading gain)
- Wider causes more power hogging on downlink from retransmitted noise
- Downlink can only support a limited number of users

Uplink Frequency

- Not a major factor, use convenient band

Downlink Frequency

- Limited power in downlink makes minimizing path loss important
- This is THE major factor in determining capacity

For More Information

- ☐ Read SSWBT Proposal in DCC'99 or AMSAT 2000 proceedings
- ☐ Check out <http://www.ettus.com/sswbt>
- ☐ Email matt@ettus.com
- ☐ Join TAPR Space mailing list